A NOTE ON PHASE 1 μe SCATTERING AND MUON BREMSSTRAHLUNG EXPERIMENTS AT WESTON

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In a memorandum dated April 1968, Richard Wilson has outlined the essential features of a facility at Weston that could be used for many different experiments with a 100 GeV muon beam, and in particular discusses (1) measuring the total cross section for interactions of virtual photons with nucleons by means of muon inelastic scattering, and (2) the production of ρ-mesons by virtual photons. The proposed facility extrapolates from the experiments performed by Perl, et al, at SLAC, and by the Case-Harvard-McGill-Stanford collaboration at the AGS. In addition to a 1 meter hydrogen target it would include magnets to analyze the momenta of the incident muons, the inelastically scattered muon and other final state charged particles, trigger counters and wire plane spark chambers, and large total absorption photon counters with a few percent resolution such as have been studied by Hofstadter and others.

Two major sources of background triggers in any hadron production experiment using this facility would be (1) μe scattering events (knock-on electrons), and (2) muon bremsstrahlung events ($\mu + N \rightarrow \mu' + N + \gamma$). Of course both of these processes are of considerable

interest in their own right. It is obvious that since they are important

sources of background in hadron measurements, the proposed facility

could also be modified to study both of them, though probably not

simultaneously, since the knock-on cross section is orders of magni-

tude larger than the bremsstrahlung cross section. Both experiments

are in the Phase I category in the sense that they could probably be

performed prior to installation of the complete facility. In fact, an

interesting region of the bremsstrahlung spectrum could be studied

using conventional magnets.

In the muon inelastic scattering experiment at the AGS, knock-on

triggers were largely eliminated by the kinematic requirement that an

incident, 12 GeV muon lose at least 3 1/2 GeV by interacting in the

target before triggering the system. Except for very high energy loss

processes, the kinematic elimination of knock-on triggers will not be

feasible at Weston, since a 100 GeV muon can lose more than 80% of

its energy to an electron. Therefore, as Wilson points out, a non-

coplanarity requirement will have to be included in the trigger for any

hadron production experiment. Conversely, a coplanarity require-

ment could be used to insure that most triggers resulted from

scattering events. If the incident muon momentum, the opening angle

and momenta of the final state muon and electron were measured, and

the electron and muon identified as such, the kinematics would be

overdetermined. Therefore, it appears that μe scattering could be

studied even if the incident muon energy were <u>not</u> very well known.

The existence of total absorption photon counters with energy

resolution on the order of 5% would imply the possibility of carrying

out muon bremsstrahlung measurements without measuring the in-

cident muon momentum too well. In this case the trigger would include

a maximum two-charged particle requirement (the inelastic muon and,

for high momentum transfer events, the recoil proton). Measurement

of the μγ opening angle and the energies of both final state particles

would then determine the kinematics for any "elastic" event, i. e. ,

events with no other particles save the recoil proton in the final state.

The major advantage in planning experiments that do not require

momentum analysis of both the incoming and outgoing particles is

obvious. Large superconducting magnets are going to be required in

the facility. (For example, a 72 inch, 100 kilogauss dipole gives

$\frac{\Delta\theta}{\Delta p}$ = 6. 4 x 10^{-4} rad/GeV for a 90 GeV particle and 2. 2 x 10^{-3} rad/

GeV at 50 GeV.) Clearly, it will be easier to obtain one magnet of

this description than two during Phase I operations at Weston.

Certainly their design and construction should be pushed as soon as

possible so that in fact the full facility can be set up soon after the

muon beam is installed. However, performing the μe and/or the

bremsstrahlung experiments at an even earlier stage would provide

an opportunity to study the 100 GeV, 10^5/sec, muon beam we hope

will exist soon after the accelerator is available to experimenters, as

well as to do some worthwhile physics.

It is worth noting that an experiment to measure the very high

energy part of the muon bremsstrahlung spectrum might well be

performed even before high field magnets are available, since

momentum analysis of the accompanying 10-15 Gev final state muons

could be performed using more conventional low field magnets. In

addition, the high trigger background in other parts of the spectrum

could be largely eliminated by imposing a kinematic cutoff on the

scattered muon (as in the AGS experiment) in a high energy loss,

wide angle region. In fact, the most interesting physics is here,

since these high energy loss events offer the most sensitive probe of

the muon propagator. If one superconducting magnet were available

its most advantageous role would be to analyze the incident muon

momentum and thus to overdetermine the kinematics.

Low counting rates might prove to be the major reason for post-

poning the bremsstrahlung experiment beyond Phase I. Assume

10^5 100 GeV muons incident per second upon a 1 meter long liquid

hydrogen target, and consider final photons with energies in the

range 90 $\pm$ 2 GeV and angles within $\pm$ 0.2° of the forward direction.

Then the Bethe-Heitler differential equation for a point proton gives

1 or 2 per hour for scattered muons between 2^O and 3°. This angular

range is quite interesting, corresponding to effective masses of the

virtual muon ranging from 1. 0 to 1. 6 GeV.[*] Rates for smaller

scattering angles are expected to be much higher -- a few per minute

in the range from 1^O to 2^O. However, there is considerably less

physics interest here, since the corresponding effective muon masses

are smaller than 1 GeV.

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[*]For one of the two dominant diagrams contributing to the process.
The effective mass of the other is on the order of $M^2 = (-200 \text{ GeV})^2$.